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EDUCATIONAL TECHNOLOGY PROGRAM

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13. ABSTRACT

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A breadboard version of the LTS-3S has been assembled, and initial checkout of all system functions has been successfully carried out.

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EDUCATIONAL TECHNOLOGY PROGRAM

I. INTRODUCTION

A proposal for engineering development of an LTS-4 prototype with subsequent incorporation of the system into the Air Training Command has been submitted to the Air Force in anticipation of validation of an ATC ROC stating a requirement for such a system. In the interim, the work on the program is concentrated on developing a stand-alone terminal, LTS-3S, based upon the previously developed LTS-3 terminal. It will be electronically identical with the LTS-4 and will thus enable us to check out that element of the latter system. It will also be available for continued application studies.

II. LTS SOFTWARE DEVELOPMENT

The main effort during this reporting interval has been conversion to stand-alone operation. An Intel Corporation MCS-4 processor is being installed in two LTS-3 experimental units as part of the conversion to LTS-3S. The same processor is planned for the LTS-4 production model, and therefore most of the software will transfer directly from LTS-3S to LTS-4. Progress has been made in the area of software to the point where a feasibility demonstration of stand-alone operation has been successfully completed on a breadboard version of LTS.

A. LTL System Architecture

The Lincoln Terminal Language (LTL) runs only on a simulated processor. It is currently realized on both the Digital Equipment Corporation PDP-8 computer and the Intel Corporation MCS-4 microprocessor, as reported in the Quarterly Technical Summary dated 15 June 1973. The memory layout of the LTL simulated machine is presented in Table I. There are eight pages of 8-bit words, 128 words per page. In the LTS, the pages 0 through 3 are loadable dynamically from the fiche cards on each frame, but the remaining pages are located in read-only memory in the MCS-4.

TABLE I
MEMORY LAYOUT OF LTL SIMULATED COMPUTER SYSTEM

Pages	Read/Write Status	Permissible Data Types
0	Read/Write	Directly referenced data Indirectly referenced data LTL program
1	Read/Write	Indirectly referenced data LTL program
2,3	Read/Write	LTL program
4-7	Read Only	LTL program

In addition to the LTL processor and memory area, Monitor and In/Out routines are provided in the MCS-4. Before each LTL operation, the monitor reads and acts upon all pending In/Out commands, as in Fig. 1. On input, data are transferred from external devices to the

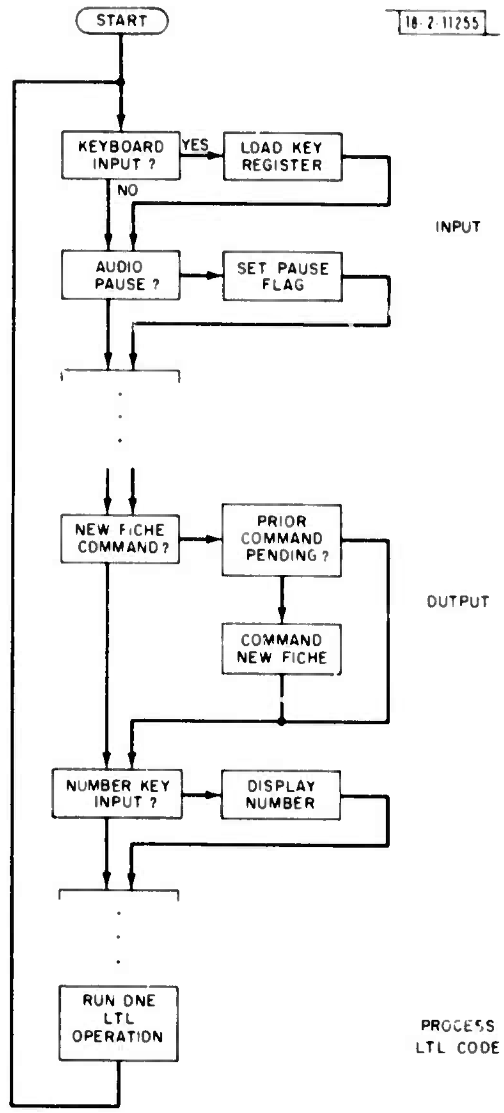

Fig. 1. Flow of Monitor Program.

communication area in LTL memory, and on output, transfer is in the reverse direction. Thus, the LTL programmer controls In/Out operations merely by changing data in the communications area of LTL memory.

B. LTL Software Support and Checkout

The following software systems have been placed in operation.

(1) MCS-4 Simulator: a full-scale simulation of the Intel MCS-4 microprocessor on a PDP-8 (8K memory).

(2) LTL Simulator/PDP-8: a realization on the PDP-8 (4K memory) of the LTL processor.

(3) LTL Simulator/MCS-4: a realization on the MCS-4 of the LTL processor.

(4) Driver: a PDP-8 teletype-driven operating system to control programs and to provide debugging aid and I/O simulation for systems (1) and (2) above.

The LTL Simulator/MCS-4 was written and debugged on the MCS-4 Simulator. Next, a dummy Monitor was provided on the MCS-4 microprocessor, along with routines that permitted a LIST or STORE of LTL data and programs at the teletype; when loaded in the MCS-4, the LTL Simulator/MCS-4 was found to work perfectly. An LTL programmer's manual was written, tested, and revised; this and the LTL Simulator/PDP-8 will be used by programmers to design and debug routines for authors of lesson materials.

C. Monitor and In/Out Software Checkout

The MCS-4 system has been temporarily interfaced with an LTS-3 terminal to form a complete breadboard system. Initial checkout of the Monitor and the 48 In/Out routines was carried out on the MCS-4 with the aid of the LIST and STORE teletype facility. A Cycle Test Program was written in LTL and checked out on the LTL Simulator on the PDP-8. This breadboard of a complete LTS system is running well with the Monitor, In/Out, and Cycle Test Programs, and no deficiencies in the design or operation are apparent.

III. HARDWARE DEVELOPMENT

The major effort during this quarter has been directed at the conversion of the LTS-3 to a stand-alone terminal (LTS-3S). The X-Y positioning system has been modified such that the coarse and vernier acquisitions are performed independently, and vernier positioning is now accomplished by pulsing the X-Y servo motors. The result is an improvement in the film placement and an extension of the acquisition range. Tests and modifications of the radial tracker servo system are continuing. Closed-loop transfer functions of the servo loop are being measured under a variety of gain and damping conditions to establish a means of setting the final loop configuration.

The processor interface has been designed, breadboarded, and checked out. New cards for the data demodulator and interface have been constructed and are being tested.

A. X-Y Positioning System

The X-Y positioning system has been modified so that coarse positioning, utilizing the Image Systems resistive slide wire, and fine-positioning, utilizing the X-Y position sensing diode, are

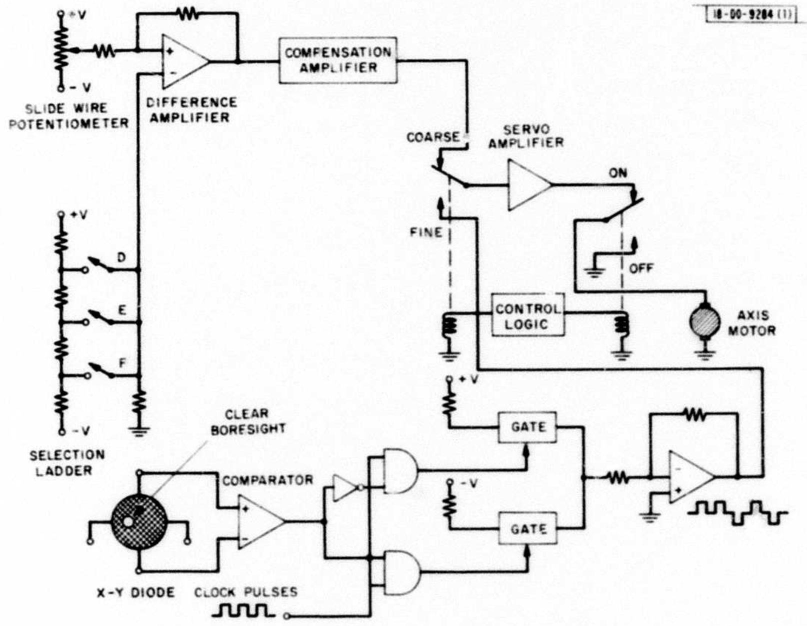

Fig. 2. Block diagram of one axis of two-stage X-Y positioning system.

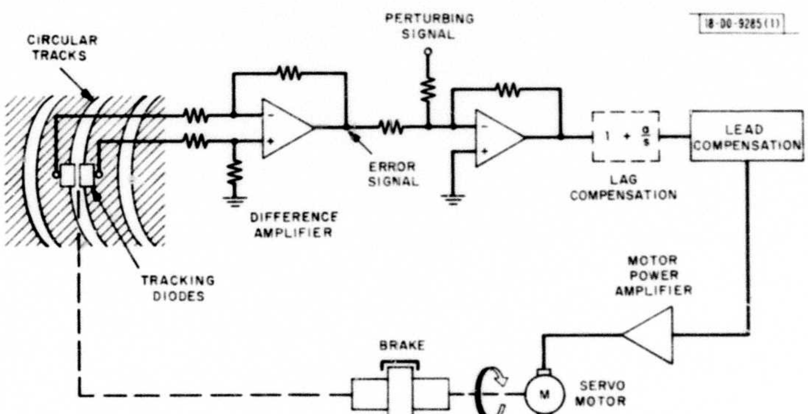

Fig. 3. Radial tracker servo system.

now done sequentially instead of in parallel by adding the two error signals. This eliminates the problem of the diode error canceling an imprecise X-Y slide wire error signal leading to an actual X-Y offset.

The fine X-Y positioning servo system is now being driven in a pulsed binary mode. Using peak pulses overcomes the dead zone of the X-Y servo motor system, while using binary pulses, based only on error zero crossings, reduces the sensitivity of the vernier positioning system to boresight light level. Initial tests indicate acquisitions in less than 1 sec to an average of less than 0.1 mm from an acquisition window of ±0.75 mm.

The coarse X-Y positioning system has been upgraded with a more precise, ruggedized X-Y which has a positioning repeatability of ±0.15 mm. This minimizes the requirement on the fine X-Y system to account for coarse mechanical X-Y errors and allows it to use most of its acquisition range for correcting errors due to film production tolerances. The worst-case coarse X-Y positioning time is less than 1 sec.

A system block diagram of the modified X-Y positioning system is shown in Fig. 2. In addition to switching between coarse and fine positioning, the block diagram also shows a control for disabling the X-Y positioning drive after initial acquisition. Previously, the X-Y was continually operating; however, it was necessary to prevent the X-Y from moving while reading data, since such motions introduced short bursts of frequency modulation which caused data errors.

B. Radial Tracker Servo System

In order to adjust the tracker servo system to have the proper frequency response for both acquisition and tracking, it is necessary to adjust both the electrical gain and the mechanical damping of the system. While the electrical gain can easily be measured directly, the mechanical damping, which is set by adjustment of a mechanical brake on the tracker motor, requires a more sophisticated measurement procedure.

A technique has been developed for electrically measuring the mechanical damping by measuring the closed-loop response of the system. Ordinarily, the closed-loop response of a system can be measured directly by varying the input in a controlled fashion. For the radial tracker, the test input would be a track with a known amplitude sinusoidally modulated pitch; this would be a difficult production task. The next best thing is to measure the open-loop response of the system and use this to calculate the closed-loop response. This should be done while the turntable is rotating in order to take into account the effects of centrifugal force and varying damping due to gravity. Since any slight X-Y error will cause the tracker to move on and off the track, this is also a difficult measurement procedure. The technique that is currently being used to characterize the closed-loop frequency response of the tracker is sketched in Fig. 3. While the servo is tracking a circular test track, the system is perturbed by addition of a small sinusoidal electrical signal. It is easy to show that the closed-loop response of the system at the perturbing frequency is the ratio of the error signal amplitude at that frequency to the perturbing signal amplitude. A typical closed-loop response for an operational LTS-3 tracker is shown in Fig. 4. Curve A is the closed-loop response when the tracker is in a horizontal position and the turntable is not rotating. Curve B is the closed-loop response when the turntable is rotating and includes the effect of centrifugal force and varying damping.

This technique has been used to identify a number of mechanical problems in one LTS-3 terminal which had heretofore operated marginally. The exact nature of the problems was difficult to diagnose until the closed-loop response was measured and compared with one of a properly operating terminal.

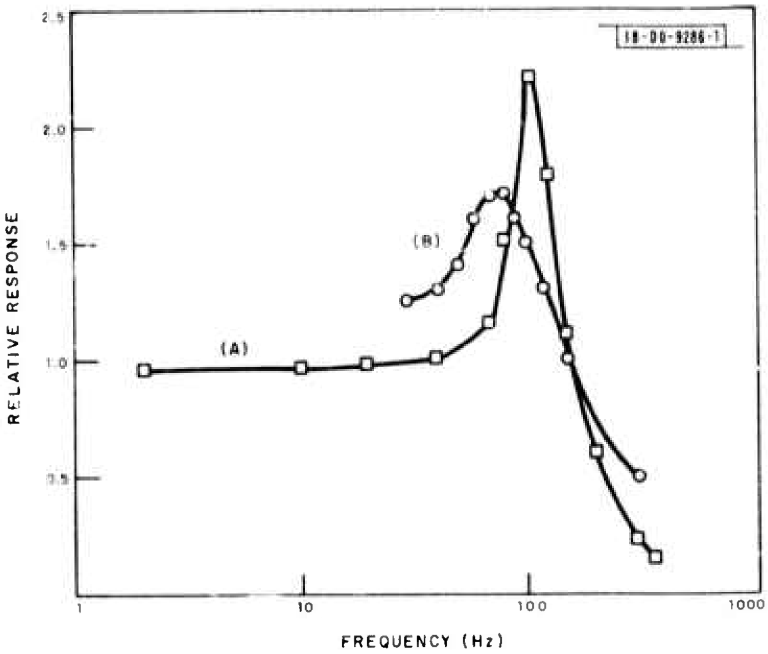

Fig. 4. Measured closed-loop tracker responses.

An attempt had been made to acquire fast lead-in spirals on LTS-3 in order to reduce the system audio delay. It was found that acquisition was not always reliable. Later, upon investigation of the closed-loop response of the tracker servo system, it was found that the closed-loop response went to zero twice per revolution at the points of maximum tracker input acceleration. This implies that there are regions where tracker acquisition is impossible because of a lack of gain. Since, for a fast lead-in, the acquisition location is a random variable depending on X-Y uncertainty, it is highly probable to miss acquisition by being at a null in the response. With a large number of slow lead-in tracks covering the X-Y uncertainty range, this problem is eliminated since, for small X-Y errors, the fraction of time per revolution spent in the acquisition window is considerably larger or, for the case of large X-Y error, the number of acquisition locations is large. Based on these results, it is the present intention to abandon the fast lead-in for LTS-3S.

Investigations have been made to improve the tracker operating margin by the improvement of the servo system compensation network. At present, the system uses lead compensation to improve the acquisition capability of the system. Experiments with the addition after initial acquisition of a lag compensation in the form of $1 + (a/s)$ have shown that the steady-state 2-Hz tracking error due to gravity and X-Y uncertainty can be substantially reduced. This technique is helpful in two ways: first, in initial acquisition, a greater amount of tolerance is allowable in the initial acquisition error, since the introduction of the lag compensation before the onset of modulation considerably reduces the acquisition error; and second, the increased low-frequency gain compensates for the loss in tracker gain because of the high modulation level of the data. Measurements are now being carried out to determine the improvement in system margin.

C. System Integration

The conversion of the LTS-3 to a stand-alone terminal involves a significant repackaging effort as well as the integration of the self processor, its interface, and the data demodulator. Wire lists for all digital logic cards have been completed, and the cards have been wirewrapped at the Lincoln Laboratory semiautomatic wirewrap facility. The demodulator analog printed circuit card layouts are complete, and the cards are being fabricated so that both the digital and analog cards can plug into a common backplane which is being wirewrapped. The results of this effort will permit a second LTS-3 to be converted to a stand-alone terminal with a minimum amount of construction time.

The power distribution system has been redesigned and repackaged. The self processor and its interface will be provided with separate +5 and −10 V supplies. The keyboard is being modified to include a LED feedback display. The display indicates keypushes which are interpreted and formatted by the self processor.

All but three of the new circuit cards have been checked out, and system cabling and mechanical modifications are under way. The new processor has been delivered and is now being tested.

D. Film Production

A second transparent door has been constructed. These doors are hung over the audio spirals at the step-and-repeat camera image plane. By configuring a clear boresight target on one door and a dark boresight target on the other, we now have the capability of photographing an 8 × 10 audio spiral with either a clear or dark boresight. The LTS-3S microfiche will be made with a clear boresight centering target on a dark background (as opposed to the dark boresight of LTS-3) to minimize offsets in the system due to light gradients across the acquisition area of the X-Y diode/light pipe assembly and to provide a convenient means of aligning the X-Y centering system. This alignment technique is accomplished by inserting over the light pipe a small fixture with a spot in the center which is referenced to the center of the turntable.

The registration of the copy fiche produced by the Kalvar printer has been improved by rearranging the film stops such that the fiche are now registered for printing as they are for photographing with the step-and-repeat camera and for the clamping press. The result is that the dimensional inaccuracy inherent in film size is not a source of error in film registration.

The production facility has continued to be used for production of test fiche and experimental lessons.

E. LTS-4 Development

1. Rotating Microscope Microfiche Reader/Selector

The mechanical construction of the reader portion of the rotating microscope microfiche reader/selector was completed at the beginning of this quarter. After a minimum effort was expended on optical focusing and electrical trouble shooting, the reader was able to acquire and track an audio spiral. The results of a very brief test indicate that the illumination appeared to be quite uniform across the radius of the spiral, and the resolution of the system appears to be limited only by the reading slit aperture rather than the combination of the reader lens and the reader slit. The reason for this improvement is the fact that the microscope is moved such that it is always centered over the portion of the film upon which the diode slit is to be imaged.

The modulation transfer function (MTF) was measured and found to be comparable to the best LTS-3 MTF. This indicates that paraxial imaging improved the system MTF despite the fact that the M = 4 photodiode aperture was wider than anticipated and therefore yielded a poorer MTF than the LTS-3 aperture (M = 5.6).

Although the design of the fiche manipulator was complete, not all the parts were ordered before the development effort was terminated at the end of the fiscal year. Those parts which have been fabricated have been stored for possible future use.

2. Image Rotator Microfiche Reader/Selector

MTF tests were run on the image rotator and reader lens assembly, and the results indicated that the rotator K-mirror assembly does not significantly degrade the system MTF. Other lenses of the same focal length as the LTS-3 reader lens were tested, and none appeared to have a better optical transfer function.

During the previous quarter, the image rotator reader/selector was upgraded to the point where reliable, repeatable operation was attained, and the short-term results were reported in the previous Quarterly Technical Summary. A test program has now been outlined to measure the long-term reliability and wear statistics of the system. Six key areas of the system have been outlined for monitoring, and within these areas a number of parameters will be continually monitored over a period of time. Table II outlines the areas and parameters to be studied. Some test procedures have already been outlined, but implementation of the test program has been delayed until after conversion of LTS-3 to a stand-alone terminal.

TABLE II

OUTLINE OF IMAGE ROTATOR READER/SELECTOR MEASUREMENTS

Subsystem	Parameters
Illumination	Lamp light power
	Lamp voltage
	Image light power
	Image uniformity
Optics	Modulation transfer function
Film Handling	Selection time
	Frame-frame delay
	Coarse X-Y accuracy
Fine Positioning	X-Y dark current error
	X-Y DC error (diode misalignment)
	X-Y 2ω error (position accuracy)
Image Rotator	Rotation frequency
	X-Y 1ω error (Dove alignment)
	FM-ing (bearing wear)
Tracker	Low-frequency gain
	Acquisition range and time
	Reset accuracy and time